

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : ORBITAL MANEUVER FMEA NO 03-3 -4005 -2 REV:11/14/67

ASSEMBLY : ENGINE SUBSYSTEM CRIT. FUNC: 2
 P/N RI : MC621-0009 CRIT. HDW: 1
 P/N VENDOR: 1186335
 QUANTITY : 2
 : 1 FOR EACH ENG SUBSYS

VEHICLE	102	103	104
EFFECTIVITY:	X	X	X
PHASE(S):	PL	LO	X OO X DO X LS

PREPARED BY: V F ROZKOS
 DES C M AKERS
 REL W J SMITH
 QE

REDUNDANCY SCREEN: A- B- C-
 APPROVED BY: APPROVED BY (NASA):
 DES [Signature] SSM [Signature]
 REL [Signature] REL [Signature]
 QE [Signature] QE [Signature]

ITEM:
 THRUST CHAMBER, REGENERATIVE, COOLED, ROCKET ENGINE.

FUNCTION:
 PROVIDES ENCLOSURE FOR COMBUSTION OF PROPELLANT AND EXPANSION AND EXPULSION OF COMBUSTION GASES TO GENERATE THRUST. CHAMBER IS FUEL REGENERATIVELY COOLED (120 CHANNELS), FABRICATED FROM A 304L S.S. LINER AND ELECTROFORMED NICKEL SHELL (REGEN JACKET CLOSEOUT). PC IS 131 PSIA. GAS WALL TEMPERATURE IS 800 F (500 F EXT). CHAMBER THROAT IS 5.8 IN. DIAMETER. BOLTED NOZZLE ATTACHMENT FLANGE WITH GRAFOIL SEAL. NOZZLE EXTENSION FLANGE IS AT AN AREA RATIO OF 6 TO 1.

FAILURE MODE:
 STRUCTURAL FAILURE, CHAMBER BURN THROUGH.

CAUSE(S):
 HIGH TEMPERATURE/LOCALIZED HOT SPOT/INADEQUATE COOLING; COMBUSTION INSTABILITY, GAS BUBBLE IN REGEN CHANNELS, IMPROPER SPRAY PATTERN, PLUGGED INJECTOR ORIFICE OR COOLING CHANNEL, MATERIAL DEFECT, WELD DEFECT, HIGH NOZZLE SIDE LOADS, GIMBAL ACTUATOR FAILURE DURING ASCENT ALLOWING NOZZLE EXTENSION TO ROTATE INTO AIRSTREAM CREATING HIGH BENDING MOMENTS. RUPTURED FILTER ALLOWS CONTAMINATION REACH REGENERATIVE CHANNELS.

EFFECT(S) ON:
 (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE

(A) LOSS OF FUNCTION - LOSS OF ONE ENGINE. POSSIBLE CHAMBER EXPLOSION DUE TO BURN THROUGH.

(B) LOSS OF INTERFACE FUNCTION - POSSIBLE DAMAGE TO AFT RCS, TPS OR POD/AFT FUSELAGE STRUCTURAL DAMAGE.

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(C) POSSIBLE EARLY MISSION TERMINATION. REDLINE ADDITIONAL PROPELLANT FOR RCS BACKUP DEORBIT. NEXT PLS DEORBIT IF SUFFICIENT PROPELLANT NOT AVAILABLE.

(D) POSSIBLE LOSS OF CREW/VEHICLE - POSSIBLE FIRE OR EXPLOSION DUE TO EXHAUST GASES OR PROPELLANT DUMPING INTO POD.

DISPOSITION & RATIONALE:

(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY (E) OPERATIONAL USE

(A) DESIGN

DETAILED THERMAL AND STRESS ANALYSES PERFORMED. STRUCTURAL FACTOR OF SAFETY 1.4 MINIMUM. BOSF (BURN-OUT SAFETY FACTOR) IS 1.4 UNDER WORST CASE CONDITIONS OF OPERATIONS WITHIN SODE ENVELOPE. LIFE CYCLE DESIGN MARGIN IS 4.0. REDUNDANT ENGINES ARE PROVIDED. ENGINE INLET FILTERS ARE PROVIDED. POST-FIRE PURGES PERFORMED TO REMOVE RESIDUAL FUEL FROM REGEN JACKET AND INJECTOR. RESIDUALS PURGED FROM BALL VALVE CAVITY AFTER LANDING. THE BI-PROP VALVE REDUNDANT SEALS PREVENT PROPELLANT LEAKAGE INTO CHAMBER. GN2 TRICKLE PURGE APPLIED TO ENGINE ON GROUND TO PREVENT AIR/ MOISTURE MIGRATION INTO INJECTOR. THROAT PLUG WITH DESICCANT INSTALLED AFTER LANDING TO LIMIT CONTAMINATION POTENTIAL AND PROTECT ENGINE WHEN TRICKLE PURGE DISCONNECTED.

(B) TEST

QUALIFICATION TESTS

VIBRATION TESTS AT ENGINE LEVEL. HOT-FIRE TEST PROGRAM - VERIFICATION OF PERFORMANCE WITHIN SPEC ENVELOPE. TCA LEVEL - 1216 FIRINGS, 6941 SEC DURATION, 20 BOMB STABILITY TESTS. ENGINE LEVEL - 760 FIRINGS - 13251 SEC DURATION. 12 THERMAL MARGIN OFF-LIMITS TESTS. SYSTEM LEVEL - 498 FIRINGS, 14831 SEC DURATION. DEFINITION OF PERFORMANCE UNDER ABNORMAL CONDITIONS - EFFECT OF PROPULSION SYSTEM FAILURES, PROPULSION SYSTEM OPERATION IN CONTINGENCY MODES.

ACCEPTANCE TESTS

DETAILED VISUAL INSPECTION. WELD INSPECTIONS. INDIVIDUAL CHANNELS FLOWED & LEAK CHECKED. PROOF PRESSURE & LEAK TESTING OF CHAMBER, ELECTROFORMED NICKEL TO STAINLESS STEEL BOND AND WELDS. VERIFICATION OF HEAT-FLUX COMPATIBILITY BETWEEN INJECTOR AND CHAMBER. MINIMUM OF TWO 30-SECOND FIRINGS OF COMPLETE ENGINE ASSEMBLY FOR PERFORMANCE VERIFICATION. CLEANLINESS VERIFICATION.

GROUND TURNAROUND

V43CBO.211 PERFORMS LEAK CHECK OF OME CHAMBER/ NOZZLE JOINT FOR FIRST FLIGHT AND ON 5-FLIGHT INTERVALS.

V43CEO.010 DEFINES ENGINE PROTECTION REQUIREMENTS (THROAT PLUG AND TRICKLE PURGE); THROAT PLUG INSTALLATION OR TRICKLE PURGE INITIATION REQUIRED WITHIN 24 HOURS OF LANDING.

V43CEO.050 REQUIRES PURGE OF RESIDUAL PROPELLANT FROM BALL VALVE CAVITY WITHIN 14 DAYS OF LANDING.

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V43CEO.020 DEFINES DETAILED VISUAL INSPECTION OF OME INJECTOR, ACOUSTIC CAVITIES, COMBUSTION CHAMBER WALL, AND NOZZLE; DOCUMENTATION IS REQUIRED FOR ANY ANOMALOUS INDICATIONS (PERFORMED EACH FLIGHT).
V43CEO.030 DEFINES DETAILED VISUAL INSPECTION OF ENGINE COMPONENTS WITHIN ENGINE BOX (REMOVAL OF HEAT SHIELD REQUIRED); REQUIREMENTS TO BE CARRIED OUT WHENEVER POD IS REMOVED (AT LEAST EVERY 5 FLIGHTS).

V43CBO.275 PERFORMS PERIODIC LEAK CHECK OF ENGINE PLUMBING DOWNSTREAM OF ENGINE BI-PROP VALVE EVERY FIVE FLIGHTS.

V43CEO.090 REQUIRES PROPELLANT SAMPLE (SE-S-0073) FOR SECOND FLIGHT AND ON A CONTINGENCY BASIS.

V43CHO.010 PERFORMS WATER INTRUSION INSPECTION AFTER FIREX USAGE ON PAD.

(C) INSPECTION

RECEIVING INSPECTION

MATERIALS AND PROCESSES CERTIFICATIONS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL

CLEANLINESS TO LEVEL 200 FOR MMH AND 200 A FOR NTO AND CORROSION PROTECTION PROVISIONS ARE VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

MANUFACTURING, ASSEMBLY AND INSTALLATION PROCEDURES ARE VERIFIED BY INSPECTION. CRITICAL DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. DIMENSIONAL INSPECTION OF THRUST CHAMBER AFTER MACHINING IS VERIFIED BY INSPECTION.

CRITICAL PROCESSES

NICKEL PLATING THICKNESS IS VERIFIED BY INSPECTION. THE WELDING PROCESS AND VERIFICATION THAT WELDS MEET SPECIFICATION REQUIREMENTS ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

PENETRANT AND RADIOGRAPHIC INSPECTION OF WELDS ARE VERIFIED BY INSPECTION. ULTRASONIC INSPECTION OF THRUST CHAMBER FORGING IS VERIFIED BY INSPECTION. CHAMBER PENETRANT INSPECTION IS VERIFIED BY INSPECTION.

TESTING

TEST EQUIPMENT AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. ACCEPTANCE TEST IS VERIFIED BY INSPECTION. CHAMBER LEAK TEST IS VERIFIED BY INSPECTION. CHAMBER FLOW CALIBRATION IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

HANDLING, PACKAGING, STORAGE AND SHIPPING REQUIREMENTS ARE VERIFIED BY INSPECTION.

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(D) FAILURE HISTORY

LINER/CLOSEOUT DISBONDING WAS OBSERVED ON A DEVELOPMENT ENGINE. OVERHEATING OCCURRED DURING BOSF TESTING. MISSION RULES/REDLINES AVOID OPERATION IN REGIMES WHERE FAILURE PREDICTED.

CAR AC4020 RECORDS ACOUSTIC CAVITY LIP EROSION ON A POD QUAL ENGINE DUE TO LOW CYCLE FATIGUE CAUSED BY HIGH WALL TEMPERATURES. ESTIMATED WALL TEMPERATURE WAS 1900 DEG F., NOMINAL TEMPERATURE 800 DEG F. (100 MISSION LIFE). THE HIGH TEMPERATURE WAS A RESULT OF MISALIGNED INJECTOR FACE PLATES. PROCESSES WERE MODIFIED AND ADDITIONAL INSPECTIONS ADDED. BONDING OF THE INJECTOR PLATES IS REQUIRED PRIOR TO HYDRO-TEST TO LIMIT WEAR ON THE ALIGNMENT PINS. SUBSEQUENT INJECTORS TESTED WITH TEFLON LINER WHICH EXTENDS TO CAVITY LIP. ALL FLIGHT ENGINES EXCEPT SN 101M AND SN102 WERE TESTED WITH THE LONGER TEFLON LINER. SN 102 WAS USED ON OV-099, 51L; SN 101M IS ASSIGNED TO OV-104. 191 TESTS WERE PERFORMED AFTER EROSION BEGAN. NO MEASURABLE EFFECT ON PERFORMANCE OR OPERATION. DETAILED INSPECTIONS ARE PERFORMED AFTER EACH FLIGHT.

(E) OPERATIONAL USE

FAILURE MAY BE DIFFICULT TO DIAGNOSE. ISOLATE FAILED ENGINE AND COMPLETE MISSION REQUIREMENTS USING CROSSFEED FOR PROPELLANT UTILIZATION. REDLINE ADDITIONAL PROPELLANT FOR RCS BACKUP DEORBIT. NEXT PLS DEORBIT IF PROPELLANT FOR RCS BACKUP NOT AVAILABLE. POSSIBLE MISSION IMPACT. DECREASED PROPELLANT AVAILABLE FROM OMS TO RCS THROUGH INTERCONNECT FOR ON-ORBIT OPERATION.